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The Dust Coma of Comet Austin (1989c1)

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Thermal-infrared (10 and 20 micron) images of Comet Austin were obtained on UT April 30.6, May 1.8, 2.8, and 3.6, 1990. We used the NASA-Marshall Space Flight Center 20-pixel bolometer array at the NASA 3-meter Infrared Telescope Facility in Hawaii. We obtained 10.8 micron (FWHM = 5.3 microns) maps with maximum dimensions of 113 arcsec (57,500 km.) in R.A. and 45 arcsec (23,000 km.) in Declination, with a pixel size of 4.2x4.2 arcsec. A smaller, 45x18 arcsec, map was obtained in the 19.2 micron (FWHM = 5.2 microns) bandpass. At the time of these observations Comet Austin's heliocentric and geocentric distances were 0.7 AU and 0.5 AU respectively. The peak flux density (within the brightest pixel) was 23 ± 2 Janskys for the first three dates and only marginally lower the last day; i.e., within the observational uncertainties we found no evidence for day-to-day variability like that observed in Comet Halley. A dynamical analysis of the morphology of the extended dust emission is used to constrain the size distribution and production rate of the dust particles. The results of this analysis are compared with similar studies carried out on comets P/Giacobini-Zinner, P/Brorsen-Metcalf, P/Halley, P/Tempel 2, and Wilson (1987).

THE SIZE DISTRIBUTION OF ASTEROIDS FROM IRAS DATA

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Taking profit of the whole IRAS data base on asteroid diameters and albedos, we have analyzed the overall size distribution of asteroids, on the basis of different statistical methods aimed to derive reliable diameter estimates for the objects lacking an individual IRAS observation. We find that asteroids belonging to dynamical families and to the Flora region show a different behavior with respect to the rest of the asteroid population. In fact, apart from the Flora region, non-family asteroids have always size distributions characterized by a strong change in slope at diameters around 150 km, with the differential power-law distribution exponent passing from values around 3 or more at large sizes, to about 1 at smaller ones. On the other hand, in the Flora region, as well as for family asteroids, a steep slope is observed also at small sizes. We stress the importance of the present results for further studies of the process of collisional evolution of asteroids.

GROSS-FRAGMENTATION OF METEORIDS AND BULK DENSITY OF GEMINIDS FROM PHOTOGRAPHIC FIREBALL RECORDS; Z.Ceplecha, Astronomical Institute, Czechoslovak Academy of Sciences, 251 65 Ondrejov, Czechoslovakia; R.E.McCrosky, Smithsonian Astrophysical Observatory, 02138 Cambridge, USA.

The explicit solution of the drag and ablation equations of a single non-fragmenting meteoroid moving in any actual atmosphere was generalized by allowing for one or more points, where a sudden gross fragmentation can occur. Using this generalized solution, the distances along the meteoroid trajectory can be computed for any choice of input parameters and compared with the observed distances flown by the meteoroid. For the most precise and long fireball trajectories, the least-squares solution can thus yield the initial velocities, the ablation coefficients, the positions of gross-fragmentation points and the terminal mass. At a gross-fragmentation point, the ratio of the main mass to all the remaining fragments can be computed. The photometrically-determined meteoroid mass can be compared with the dynamic mass determined from our gross-fragmentation model and thus the meteoroid bulk density can be evaluated.

This gross-fragmentation model was used for computation of bulk densities of the Geminid meteoroids. From all the Prairie Network (PN) Geminids, only two (G15 and G54) have enough long and deep trajectories, enough observed change of velocity and enough precise heights and lengths measured for individual time-marks, that they allow the complete application of our gross-fragmentation model. If the previous non-gross-fragmentation model was used for G15 and G54, the time sequence of residua of the solutions exhibited a prevailing systematic part ($\approx 80\%$) and the bulk densities came out close to 1.0 g/cm^3 . If the new gross-fragmentation model was applied to the same observational data, the systematic part of the time sequence of residua was completely gone and the bulk densities resulted in 3 to 4 gr/cm^3 . Thus the value of the bulk density of Geminids, 1 g/cm^3 , advocated for a long time and determined by indirect methods, may have been caused by neglect of the gross-fragmentation effects on the meteoroid motion. This may, of course, hold also for about 25% of PN fireballs, which exhibit a systematic part in the time sequence of residua of the non-gross-fragmentation solutions. The gross-fragmentation model should be applied to all suitable PN fireballs with such systematic residua in non-gross-fragmentation solutions.

We applied the same gross-fragmentation model to the terminal part of the Lost City fireball data. The bulk density, the rough position of the fragmentation point, the shape coefficient and the terminal mass are known in this case and since their values computed from our gross-fragmentation model came out quite close to this reality, the bulk densities of G15 and G54 Geminids are about 3 or 4 times greater than densities of the Geminid meteoroids postulated so far.

Why use Space Telescope?

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NO ABSTRACT AVAILABLE

GASpra: THE SCIENTIFIC ISSUES

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As we write, *Galileo's* final Gaspra encounter parameters have not been determined nor is the spacecraft even healthy. Here we outline some scientific issues about main belt asteroids (especially S types) that can be addressed if the prime objectives for the camera (SSI) and NIMS instruments are met this October. They include: (a) one high resolution (full frame) picture at $\sim 90^\circ$ phase; (b) multi-filter images at moderate resolution; (c) resolved imaging throughout a rotation period; and (d) low phase angle IR spectral mapping by NIMS (few dozen resolved nimsels).

Calibration of Ground-based Observations. As the first asteroid to be studied closely by spacecraft, it is important to learn how well our pre-encounter inferences about Gaspra represent reality. In a 7 December 1990 *Galileo* Project memo prepared by one of us (CRC), various physical parameters were proposed for adoption as "nominal." These include the oft-quoted, but highly uncertain, 16 km diameter (it is more likely to be smaller than larger), values for spin period, axis orientation, and body shape. Groundbased observers may improve on these estimates during Gaspra's current apparition. We need to assess how well we have done and where we went wrong so we can understand how reliably we can trust groundbased results for *other* asteroids, which is all we will ever have for most of them.

Compositional Nature of S-Types. Gaspra appears (from 8-color photometry) to be an olivine-rich S-type, which contrasts with pyroxene-rich Ida (*Galileo's* second asteroid target). The two objects should roughly bracket the range of S-types. If Gaspra is geochemically differentiated, most models suggest that it could well show prominent mineralogical variations reflecting the differentiation process. SSI multispectral images should reveal and distinguish units that are metal-rich, pyroxene-rich, and olivine-rich; if units are of large enough spatial scale, NIMS can obtain refined and mineralogically diagnostic spectra of them. Silicate variations can be interpreted in terms of differentiation using the interpretational approach that Gaffey (1984, *Icarus*, **60**, 83) first applied to hemispheric data of Flora. Conceivably, Gaspra either (a) is a monomineralic fragment or (b) has compositional variations on a scale of less than a few 100 meters, in which case the issue of primitive vs. differentiated nature may go unresolved.

Collisional/Cratering History. Gaspra is almost certainly a fragment of a larger body according to standard calculations of collisional lifetimes; it may be a "Flora family" member. Its highly irregular shape (compatible with 1989 PB-like duplicity or "rubble-pile" structure) may, at high resolution, reveal much about the fragmentation process. For a wide variety of possible projectile populations, and independent of whether Gaspra is a "fresh" fragment or overdue for collisional disruption, the observed crater population (including degradation states and density variations) should be interpretable in terms of the as-yet-unknown production function. Gaspra must be in a state of quasi-saturation equilibrium. It is not clear that the age of the body or its inherent strength can be determined from *Galileo* data.

Surface Morphology. Gaspra is the first case for studying questions of regolith retention, development, and character on a small, heliocentric body (it is near the threshold size for a strong body to retain regolith according to Housen *et al.*, 1979, *Icarus*, **39**, 317). Surface morphology on an iron-rich object, which Gaspra may be, is particularly uncertain.

THE LIFETIME OF BINARY ASTEROIDS VS. GRAVITATIONAL ENCOUNTERS AND COLLISIONS

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Abstract. In this paper we investigate the effect on the dynamics of a binary asteroid of the near encounter with a third body. The dynamics of the binary is modelled by the two-body problem perturbed by an approaching body in the following ways: either direct collisions with a component of the binary or near encounters. In the case of collisions, two sub-cases are examined: collisional ejection and collisional disruption. In the case of gravitational encounters, three sub-cases are considered: very close, close and far encounters. In each case, the typical value of the two-body energy variation is estimated, and a random walk for the cumulative effect is assumed. The results are applied to the cases of 146 Lucina, 216 Kleopatra, 532 Herculina and 1220 Crocus which are binary candidates. The main conclusion is that the collisional disruption is the dominant effect, giving lifetimes comparable with the age of the solar system.

ON THE EFFECTS OF THE OBSERVATIONAL SELECTION IN THE MODERN DISCOVERIES OF ASTEROIDS

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The sample of the numbered minor planets discovered at the Crimean Astrophysical Observatory is discussed and compared with the asteroid "collections" of some other observatories. The statistical features of the examined samples are found to be similar despite of the variety of the observational conditions depending on the geographical positions of the observatories, used telescopes and techniques, etc. It follows that the selection effects must be here the same for all considered samples.

Sincerely N.Chernykh

THE TRIPLET $d^3\Delta - a^3\Pi$ AND ASUNDI $a'^3\Sigma^+ - a^3\Pi_r$ BANDS OF THE NEUTRAL CO IN THE COMET SCORICHENKO-GEORGE(1989e₁) SPECTRUM.
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The comet Scorichenko-George (1989e₁) spectrum obtained by V. L. Afanas'ev, A. I. Shapovalova and the author with the help of a TV spectral scanner of the 6-m reflector (BTA) at the Spectral Astrophysical Observatory of the USSR Academy of Sciences (Pastukhov's Mount) shows to have the emission bands of the triplet and Asundi systems of the neutral CO. This leads to suggest the comet nucleus includes the formaldehyde HCO or polyformaldehyde (H₂CO)_n which gives birth to HCO⁺-ions which if recombined and photodissociated result in CO-radicals at $d^3\Delta$ and $a'^3\Sigma^+$ levels necessary to excite the CO-emissions in the triplet and Asundi system bands. The peculiarities of the rate production of CO-gas and the lightcurve of Comet Scorichenko-George (1989e₁) are discussed.

SOLAR ACTIVITY INFLUENCE UPON THE LIGHT CURVE OF COMETS P/HALLEY (1986 III) AND P/CHURYUMOV-GERASIMENKO (1982 VIII).
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It is shown that despite the negative results obtained by Prof. S. V. Orlov about the absence of a correlation between the total brightness variations of Comet P/Halley (1910 II) and solar activity (Wolf number) Comet P/Halley (1986 III) total brightness correlates with changes in the solar activity indices and the solar wind velocity.

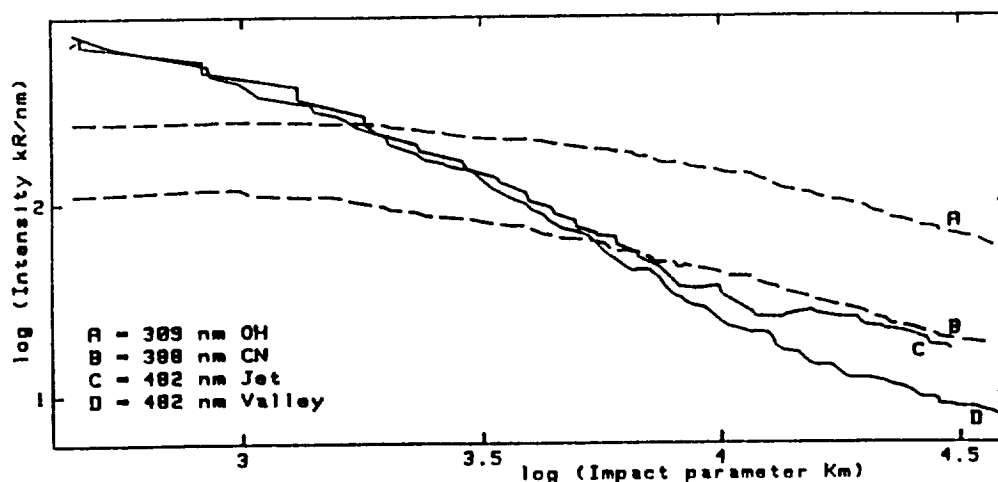
A statistically reliable correlation between the outbursts of brightness and brightness variations of the shortperiodic Comet Churyumov-Gerasimenko (1982 VIII) and the level of the solar activity have been found out.

DUST AND GAS JETS. EVIDENCE FOR A DIFFUSE SOURCE IN HALLEY'S COMA

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Monochromatic images constructed in using the data obtained with the Vega 2 three-channel spectrometer provide the spatial distributions of molecular and dust-scattered intensities inside the field of view scanned by the instrument, which is an angular sector centered on the nucleus having an aperture of 50° and an extension of 40 000 km. Two well-contrasted jets appear in the monochromatic images at the wavelengths of molecular emissions : OH, NH, CN, C_2 , C_3 . At the same locations, dust jets are also present. Dust jets are less apparent because the dust solar-scattered intensity decreases with cometocentric distance as $r^{-\alpha}$ with $1 < \alpha < 1.6$ and is very weak at $r = 20000$ to 40000 km, if compared to the intensity close to the nucleus. The spatial distributions and radial profiles of the solar-scattered intensity at 377, 482 and 607 nm are presented. A pixel-to-pixel ratio of these images shows that the intensity of continuum is slightly colored : bluer close to the jets in the 20000-30000 km region and redder between the jets in a region called "valley" at distances smaller than 30000 km.

Present observations provide a good evidence for the existence of a diffuse source responsible for the release of molecules that build the gas jets and form the CO extended source measured by the Giotto NMS experiment. Following a Mie calculation, the coloration of the continuum shows that the dust grains have a submicronic size. They constitute a population of tiny grains which was detected by the dust-impact analysers of Giotto and Vega at distances of 20000 to 40000 km. In this range, on the sunlit part of the coma, dust models predicted a cut-off at the lower mass end of the particle mass distribution function which was not observed. The figure below gives two log-log intensity distributions of dust-scattered continuum at 482 nm along two radii in the more contrasted jet (C) and in the valley (D). The distributions of OH (A) and CN (B) at their maximum has also been plotted.



The Coma of Comet P/Schwassmann-Wachmann 1

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We have obtained spectra of comet P/Schwassmann-Wachmann 1 (SW1) during observing runs in December 1989 and December 1990. The data were obtained using the Large Cass Spectrograph (LCS) on the 2.7 m telescope of McDonald Observatory. The LCS has a long slit and images onto a TI 800 \times 800 CCD detector. During both runs, the comet was extended and a CO⁺ coma was detected. In addition, we detected emission due to CN and an unknown species during the December 1989 observations but *not* during the December 1990 observations.

During December 1990, we observed the strengthening of the CO⁺ emissions by a factor of 2.5 in the course of one day. However, during this time, the continuum magnitude remained unchanged.

We will present these data and discuss the implications for formation of the CO⁺. We can rule out photoionization of CO to form the observed CO⁺ in SW1. We will also demonstrate evidence for non-equilibrium conditions in the CO⁺ coma of this comet.

OBSERVATIONS OF COMETARY PARENT MOLECULES WITH THE IRAM RADIO TELESCOPE; P. Colom, (Observatoire de Paris-Meudon), D. Despois (Observatoire de Bordeaux), G. Paubert (IRAM, Granada), D. Bockelee-Morvan and J. Crovisier (Observatoire de Paris-Meudon).

Spectroscopic observations at millimetre wavelengths of comets /Brorsen-Metcalf 1989 X, Austin 1989c1 and Levy 1990c were conducted at the IRAM 30-m radio telescope. Hydrogen cyanide (HCN), already detected in /Halley, was observed through two transitions. Formaldehyde (H₂CO) was unambiguously identified. Hydrogen sulfide (H₂S) and methanol (CH₃OH) were detected for the first time in comets, through several transitions. In addition, observations of the transitions of several other molecular species (HC₃N, H₂CS, SO₂, OCS...) were unsuccessful, but yielded significant upper limits.

The possibility to observe several transitions of the same species at a time (up to 12 transitions of CH₃OH were observed) gives stringent constraints on their excitation conditions. The observed molecules appear to be rotationally relaxed, as expected from excitation models.

HCN and H₂S are minor species, with production rates relative to water of 0.3 to 1.8 10^{-3} for HCN (depending on the comet), of 2 10^{-3} for H₂S. H₂CO, if one assumes it is a parent molecule, has a production rate of 1.4 to 4 10^{-3} that of water (depending on the comet), which is at least one order of magnitude smaller than the production rates of H₂CO in comet Halley inferred from infrared and centimetric radio observations. CH₃OH is a more abundant species with a production rate about 10^{-2} that of water; this implies that the vibrational bands of CH₃OH should significantly contribute to the cometary 3.2-3.6 micron emission.

The existence of these interstellar molecules in cometary nuclei, the absence of others (SO₂, OCS...), the cold storage implied by the presence of species with low sublimation temperatures (such as H₂S) are constraints which will have to be taken into account in order to achieve a consistent scenario of the formation of cometary material and cometary nuclei.

The Appearance of the 7.4-day Periodic Variation in the Spatial Profiles of C₂, CN, NH₂ and O(¹D) in Comet Halley

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Spatial profiles of C₂, CN, NH₂ and O(¹D) in comet P/Halley taken on April 14.3 and 15.3, 1986 show clear evidence of the effects of the 7.4-day periodic variation seen in photometric observations. The profiles show unusually large changes in shape between the two nights. Analysis with the usual steady-state models would require unphysically large changes in scale lengths. However, a time-dependent model for the spatial distributions of neutral species in comets does show that the unusual shapes are caused by the 7.4-day periodic variation in gas production seen in photometry. The time-dependent production rate at the source was adapted from the "C₂ light curve" of Schleicher, et al. (1990, *Astron. J.* **100**, 896-912). Variations in the profile shapes are directly accounted for by the periodic variations in gas production. Furthermore, we are able to reproduce the highly variable profiles with a model that uses only standard scale lengths reduced to the appropriate heliocentric distance (1.38 AU) and adopted from observations of Halley and other comets. There is a small phase lag of about 6 hours between the photometric light curve and the actual source rate time dependence. This expected phase lag is attributable to the filling time of the gas in the photometric aperture. An amplitude for the variation in gas production, which is 20% larger than that present in the photometry, is also required. This is quite consistent with the photometric aperture time smear. Although CN, C₂, OH and dust continuum seem to show the same variations, this is the first demonstration that NH₂, which is the likely dissociation product of NH₃, and O(¹D), which is a direct tracer of H₂O in the inner coma, also follow the same time dependence.

Asteroids, Comets, Meteors 1991: Flagstaff, Arizona, June 24-28, 1991

RADIO SPECTROSCOPY OF COMETS: RECENT RESULTS AND FUTURE PROSPECTS; J. Crovisier (Observatoire de Paris-Meudon).

After the P/Halley observing campaign, cometary radio astronomy entered a new phase recently with the observations of P/Brorsen-Metcalf 1989 X, Austin 1989cl and Levy 1990c. Successful spectroscopic observations were conducted at millimeter and submillimeter wavelengths with three different instruments (Institut de Radio Astronomie Millimetrique, Caltech Submillimeter Observatory and Swedish-ESO Submillimetre Telescope).

Hydrogen cyanide (previously detected in comets Kohoutek 1973 XII and P/Halley) and formaldehyde (previously tentatively identified in P/Halley) were observed in the three comets. Two new cometary molecules were identified in comets Austin and Levy: hydrogen sulfide and methanol. to test excitation models. They significantly increase the credibility of the molecular production rate determinations.

The abundances relative to water of these molecules are of the order of 10^{-3} for HCN and H_2S , of a few 10^{-3} for H_2CO , of 10^{-2} for CH_3OH . Radio spectroscopy has thus access to relatively minor constituents as well as to relatively complex species such as methanol. This technique appears to be a powerful tool for studying the chemical composition of the coma. It seems probable that several other molecular species (or ions) could still be observed. The future prospect of cometary radio spectroscopy, at centimetric, millimetric and submillimetric (for both ground-based and space instruments) wavelengths, will be reviewed.

THE GREAT ASTEROID NOMENCLATURE CONTROVERSY OF 1801

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In 1801 the first asteroid was regarded by most astronomers as the eighth planet of the solar system. The name to be assigned to such an important object thus assumed great significance. Its discoverer, Giuseppe Piazzi, fought hard for his right to name the object Ceres Ferdinandea. Pitted against him were German astronomers who had assigned the name Hera to the object before it had even been discovered, and French astronomers backed by none other than Napoleon, who took an active interest in the discovery. Even the popular press of the day was used to promote alternate names. The presentation of the development of this controversy is based on the original publications and letters of Europe's foremost astronomers.

THE MINOR PLANET INDEX TO SCIENTIFIC PAPERS

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DESCRIPTION

For the first time, a comprehensive index is available to minor planet researchers. The Minor Planet Index to Scientific Papers includes virtually every paper published on the subject of minor planets in the 20th century. Several hundred references from the 19th century are also included.

In all, there are nearly 12,000 entries in the Index. It is updated frequently, ensuring the most timely list available at the time of purchase. Each entry contains the following data (as applicable): name of journal, book, magazine or newspaper; title of paper, article or dissertation; author(s); date; volume number or circular number; page number. Additional fields being added are a keyword field and one containing the numbers of all the asteroids under study in each paper.

The Index has a wide scope. In addition to papers specifically dealing with asteroids, papers on related topics are included. These include the extinction (impact) theory, meteorites and comets. All doctoral theses, books, and magazine articles are included, as well as the New York Times and Times of London database. This Index is far more comprehensive than Astronomy & Astrophysics Abstracts.

AVAILABILITY

Order forms for the Index are available from the author. With the use of a database management program purchasers may search or sort the database on any field or combination of fields. Since the database exceeds two megabytes, it is compressed and placed on one 1.2 Meg IBM-compatible 5.25-inch floppy disk. Formats available include ASCII, dBASE, WordPerfect and Lotus. A bound, laser-printed version is also available. It includes the entire index sorted three ways: alphabetically by author, alphabetically by journal, and chronologically. The laser print version costs U.S. \$100, versus U.S. \$40 for the floppy disk version.

Orbital evolution studies of asteroids near the 4:1 mean motion resonance with Jupiter

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The orbits for ten asteroids with their present osculating semimajor axes near the 4:1 mean motion resonance with Jupiter have been integrated 200 000 years into the future. The integrations were made with the 15th order RADAU integrator and perturbations due to all planets from Venus to Neptune were taken into account. The integrated asteroids are all close to the resonance at $a=2.065$ AU, including two Amor- and five Mars-crossing asteroids.

The aim of this investigation is to study the evolution of asteroids in the neighbourhood of the 4:1 resonance and the timescales of the removal of the asteroids from the resonance. To what extent the resonance is a source region of the Athen-, Apollo- and Amor asteroids and on what timescales the transitions between the different classes occur is also an interesting aspect to be considered in this study. Comparison will also be made with our earlier investigation of the 5:2 resonance.

OBSERVATIONS OF COMET LEVY 1990c IN THE [OI] 6300Å LINE WITH AN IMAGING FABRY-PEROT

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We have observed the comet Levy 1990c during 16-25 August 1990 using the MPAGE focal reducer system based Fabry-Perot etalon coupled with the 1 meter telescope of Observatory of Hoher List. The free spectral range and resolution limit of the interferometer was $\sim 2.18 \text{ Å}$ and $\sim 0.171 \text{ Å}$ respectively. Classical Fabry-Perot fringes were recorded on a CCD in the cometary [OI] 6300 Å line. They are well resolved from telluric air glow and cometary NH_2 emission. Our observations indicate that the [OI] is distributed asymmetrically with respect to the center of the comet, extending further into the tail direction. We report the spatial distribution of [OI] emission and its line width in the coma of comet Levy and an estimate of the H_2O production rate. We also address the question of parent molecule of 1D O at regions far away from the nucleus.

INTERPLANETARY MAGNETIC FIELD CHANGES AND CONDENSATIONS IN COMET HALLEY'S PLASMA TAIL

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In a time-dependant 3 dimensional MHD simulation for cometary plasmas, Schmidt-Voigt (1988) could observe the formation of condensations in the plasma tail after a 90 degree change in the interplanetary magnetic field (IMF) sweeping over the comet. From the Vega-SC, IMF measurements are available in high resolution in the vicinity of the comet. We here investigate these data for 90 degree changes in the direction and study the relation between them and optical observations of condensations in the plasma tail of Comet Halley.

THE ORIGIN AND EVOLUTION OF THE ZODIACAL DUST CLOUD.

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We have now analysed a substantial fraction of the IRAS observations of the zodiacal cloud. We have also developed a numerical model, the SIMUL model, that allows us to calculate the distribution of night-sky brightness that would be produced by any particular distribution of dust particle orbits. This model includes the effects of orbital perturbations by the planets and solar radiation, it reproduces the exact viewing geometry of the IRAS telescope, and allows for the eccentricity of the Earth's orbit. The result is a model for the variation with ecliptic latitude of the brightness observed in a given waveband as the line of sight of the telescope sweeps through the model distribution of orbits at a constant elongation angle (Dermott and Nicholson, 1989). We are now using SIMUL to model not just the solar system dust bands discovered by IRAS but the whole zodiacal cloud. Our model is based on (a) the observed distribution of asteroidal orbits, and (b) the calculated distributions of orbital elements of the dust particles after allowance for the secular perturbation of these orbits by the planets, light pressure, and Poynting-Robertson light drag.

Our main achievement this year has been the development of a new secular perturbation theory that describes the variations of the eccentricities, inclinations and semimajor axes of dust particle orbits and incorporates the effects of gravitational forces due to the planets and those due to solar radiation. In our new theory (Gomes and Dermott, 1991), the classical concepts of forced and proper elements still hold good, but the magnitudes of the forced elements no longer depend on the semimajor axes of the dust particle orbits alone, they also depend on the drag rates of the particles and thus on their sizes and orbital histories. With this new theory, we have been able to: (1) Account for the observed inclination of the background zodiacal cloud; (2) Relate the distribution of orbital elements of asteroids in the Hirayama families to the observed shapes of the IRAS solar system dustbands; (3) Show that there is clear *observational* evidence in the IRAS data for the transport of dust particles from the asteroid belt to the Earth.

Dermott, S.F., and Nicholson, P.D. Highlights of Astronomy, **8**, 259–266, 1989.

Gomes, R.S., and Dermott, S.F. To be submitted to Icarus, 1991.

A PHOTOMETRIC SURVEY OF OUTER BELT ASTEROIDS ¹

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Some recent studies have shown the fundamental role that the rotational properties can play for understanding the evolution of the asteroids belonging to the main belt and to other peculiar groups (Binzel et al., 1989; Zappalà et al., 1989). Much promising for a study of the physical features of the original planetesimals is the analysis of the Trojan asteroids and of the dynamically isolated objects (Hilda and Cybele groups), which, due to their dynamical characteristics, may have undergone less fragmentation due to collisions. In fact, both compositional studies (Vilas and Smith, 1985; Jewitt and Luu, 1990) and dynamical models (Milani and Nobili, 1985) suggest that they may have experienced an evolutionary history which may be significantly different from that of the main belt asteroids. A comparison of the rotational properties of these "primordial" objects with those of the collisionally evolved main belt asteroids could solve several problems connected with the evolution of asteroids and of the whole solar system. Since 1988 we have been carrying out an observational survey of the asteroids belonging to the Trojan, Hilda, and Cybele groups, to determine their physical properties in terms of spin periods, lightcurve amplitudes and magnitudes. At present our data set includes new photoelectric and CCD lightcurves of 21 outer belt asteroids collected at different observatories in Italy, Germany, USA, and Chile (see Table 1). No previous information on the rotational properties was available for most of the program objects.

Table 1. List of the observed outer belt asteroids

Asteroid	Group	Asteroid	Group	Asteroid	Group
617 Patroclus	Tro	3564 Talthylbius	Tro	1989 CK1	Tro
1143 Odysseus	Tro	3596 Meriones	Tro	1180 Rita	Hil
2207 Antenor	Tro	3708 1974 FV1	Tro	1748 Mauderli	Hil
2893 Peiroos	Tro	3709 Polypoites	Tro	1902 Shaposhnikov	Hil
2895 Memnon	Tro	4035 1986 WD	Tro	87 Sylvia	Cyb
3317 Paris	Tro	4348 1988 RU	Tro	909 Ulla	Cyb
3540 Protesilaos	Tro	4709 1988 TU2	Tro	1280 Baillauda	Cyb

The rotational properties that we have determined for the listed objects, represent a sensible enlargement of the existing data set. The high photometric accuracy of the collected data and their good time-sampling allowed us to compute reliable amplitudes, periods and Fourier coefficients for most of the lightcurves. It was then possible to perform a statistically significant analysis of the amplitude and of the rotational period distributions of the Trojans and study the coefficients obtained by the Fourier expansion of the lightcurves, comparing all these results with those determined for a sample of main belt asteroids in a comparable size range. A similar comparison has been performed also with the distributions obtained for the fragments produced in laboratory hypervelocity impact experiments. Preliminary results of this analysis are presented.

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¹Based in part on observations collected at the European Southern Observatory, La Silla (Chile)

ON THE STABILITY OF THE ASTEROIDAL BELT

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This paper treats a simplified model of the asteroidal belt. A secular stability criterion is obtained by varying the equation of motion. The criterion is very simple and in accordance with the available observational data. The aim of this criterion is to explain the distribution of the asteroids in the belt.

A Search for CO (1 \rightarrow 0) Emission in Comet Austin (1989c1)

M. DiSanti, M. Mumma, S. Hoban (GSFC), J. Lacy and R. Parmar (U. Texas)

High-resolution ($\lambda/\Delta\lambda \approx 2 \times 10^4$) observations of comet Austin, conducted UT 1990 May 16 and 18 with the University of Texas Infrared Echelle Spectrometer (IRSHELL) on the IRTF, were used to search for emission lines comprising the CO (1 \rightarrow 0) vibration-rotation band. The instrument used a Si-As impurity band array detector with 10 spatial elements, each 1'' on the sky, and 64 spectral channels per spatial element. The grating was set so that the central spectral channel was midway between the P3 and P2 lines, at $\nu \approx 2133.8 \text{ cm}^{-1}$.

We detected an emission at the correct Doppler-shifted position of the P3 line, at roughly the 5- σ confidence level, which filled two spectral channels and (at least) three pixels in the spatial dimension. The feature was present, however, for only the first 45 minutes of actual clock time (~ 15 min of on-source integration time) on 16 May, and was not seen in subsequent data obtained either night.

The measured P3 line flux was found to be consistent with a production rate $Q_{CO} = (8.3 \pm 2.0) \times 10^{27} \text{ s}^{-1}$, or roughly 10% that of water. This value of Q_{CO} is nearly five times larger than that reported by Budzien *et al.* (BAAS 22, 1095, 1990) based upon 09 May observations with IUE. We interpret our observations as being consistent with an outburst of duration at least ~ 3000 s. The P3 flux expected, based on the quiescent $Q_{CO} \approx 1.7 \times 10^{27} \text{ s}^{-1}$, was found to be well below the 3- σ limits obtained from our data.

Furthermore, P2 emission was not detected in any of the data. The ratio of measured P3 line flux to the 3- σ upper limit for P2 was found to be consistent with a beam-averaged coma temperature of at least ~ 30 K.

COMETARY PROGENITORS FOR SATURN-LIKE RING SYSTEMS; L. Dones, CITA/University of Toronto

Recent work (Dones 1991) has shown that tidal disruption of a large comet or asteroid during a close passage to a planet can result in the formation of a Saturn-like ring system at the present epoch. If the encounter is parabolic or weakly hyperbolic, up to $\approx 40\%$ of the mass of the stray body can be captured, even assuming no dissipation. For instance, 2060 Chiron presently crosses the orbits of Saturn and Uranus, and has a mass $M_{\text{Chiron}} = (0.01-2) M_{\text{rings}}$, where the mass of Saturn's ring system $M_{\text{rings}} = 3 \times 10^{22}$ g, and I have assumed that Chiron's radius is between 90 and 186 km (Lebofsky et al. 1984; Sykes and Walker 1991), and its density ρ_{comet} is between 0.1 and 2 g/cm³. Based on an Öpik-type calculation, the characteristic time for a body in a Chiron-like orbit ($v_{\infty} = 3.1$ km/s with respect to Saturn) to pass within a distance p of Saturn's surface is $t_{\text{enc}} = 3 \times 10^7 (R_S/p)$ years, where R_S is Saturn's radius.

The criterion for tidal disruption of a body with material strength is that the body pass within a distance q of Saturn's center, such that $q/R_S < c(\rho_S/\rho_{\text{comet}})^{1/3}$, where Saturn's density $\rho_S = 0.7$ g/cm³ and the value of the coefficient c depends on the failure mode (Boss 1991). The classical Roche criterion for a fluid body is $c < c_{\text{crit}} = 2.45$; analytic work by Dobrovolskis (1990) implies that $c_{\text{crit}} \approx 1.34 (a/200 \text{ km})^{2/3} (\rho_{\text{comet}}/1 \text{ g cm}^{-3})^{2/3}$ for an icy, non-rotating, stray body of radius a which fails by shear fracture; and a model based on smoothed-particle hydrodynamics simulations by Boss et al. (1991) gives $c_{\text{crit}} \approx 1$. The frequency of events in which bound debris is captured by the planet is not very sensitive to the exact value of c_{crit} , as long as $c_{\text{crit}} \geq 1$, for two reasons. (1) Because of gravitational focusing by Saturn, encounter probabilities per unit impact parameter are nearly independent of distance from the planet. (2) Because of the steep radial dependence of the tidal force, much more mass is captured in encounters with periapses very close to the planet's surface. From Monte Carlo simulations, I find that the rate of mass capture is only lower by a factor of two if I require $q < 1.2R_S$ for disruption, compared with $q < 2.2R_S$, the Roche criterion for a comet of unit density.

After disintegrative capture occurs, collisions among the fragments lead to a flat, equatorial ring, while collisions with inner satellites, which occur at a comparable rate, produce a population of craters with a sharp upper size cutoff and a density which declines with distance from the planet. These properties are similar to those observed for the Population II craters on the inner Saturnian satellites.

Assuming a nominal flux of Saturn-crossers, 10–100 passages within the Roche limit occur in 4.5 Gyr. Most close passages leave no bound debris, so that approximately one ring capture event occurs in the age of the solar system. However, the flux of Saturn-crossers is highly uncertain. Most such objects probably originate in a Kuiper comet belt beyond the orbit of Neptune; ongoing searches for outer solar-system planetesimals (Levison and Duncan 1990) will help determine the rate of tidal events.

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ERUPTIVE COSMOGONY OF MINOR BODIES AND THEIR INTERRELATIONS;
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The problem of the origin and evolution of minor bodies - comets, asteroids, Trojans, planetary rings, Jovian irregular and Martian satellites - is usually treated for each group from different standpoints and can hardly be considered as solved.

Nearly all the relevant questions can be answered in terms of the eruptive cosmogony if one assumes the possibility of bulk electrolysis in thick ($\sim 10^3$ km) ice envelopes of bodies like Ganymede or Callisto /1/. Electric currents of up to 10^8 A were generated as the magnetized plasma of planetary magnetospheres or solar wind flowed around them. The ices contain impurities (silicates and metal oxides, carbon-rich substances etc.) identical to carbonaceous chondrites and exhibiting electronic conduction. Therefore the current produces solid state electrolysis in ice. At pressures $\sim 10^3$ atm the electrolysis products $2H_2+O_2$ are accumulated in ice in the form of a solid solution. At concentrations of 12-15% such a solution is capable of detonation /2/.

An exploding body of $M \leq 0.5M_c$ breaks up completely, which apparently created ~ 3.9 Byr ago the main asteroidal belt. The specific features of a noncentral explosion may account for the distribution of the S, M, and C type objects in solar distance.

The explosion of a body with $M > 1M_c$ removes only a part of its material in the form of vapors of water and organics present in ices, mineral grains and large ice fragments of the outermost cold layers which also contain $2H_2+O_2$. These are cometary nuclei, their material also being capable of detonation or combustion under certain conditions. It is the combustion initiated by solar radiation in the sublimation products of ice saturated by $2H_2+O_2$ that can account for the P/Halley near-nuclear energetics² and chemistry /3/. This approach is capable of explaining also the explosive capture and properties of the Martian satellites and making certain predictions concerning their structure /4/.

The explosions of the ices of the Galilean satellites and of their fragments can account for many of their properties (differences in their ice content, in the topography of Ganymede which underwent one explosion, and of Callisto whose ices did not yet explode /5/, etc.), as well as for the origin and properties of the irregular satellites and the Trojans /6/.

As follows from the peculiar orbital distribution of the LP comets of Saturn's family, a sizable fraction of them appeared $\leq 10^4$ yrs ago escaping from deep in Saturn's sphere of action. This allows the dating of the possible explosion of the ices of Titan which created its atmosphere and Saturn's rings, as well as the reservoir of cometary nuclei between the orbits of Jupiter and Saturn which presently replenishes the Jovian family /7/. Some of the predictions made on this basis have already been confirmed, the others awaiting confirmation.

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THE SIZES AND SHAPES OF (4) VESTA, (216) KLEOPATRA, AND (381) MYRRHA
FROM OCCULTATIONS OBSERVED DURING JANUARY 1991

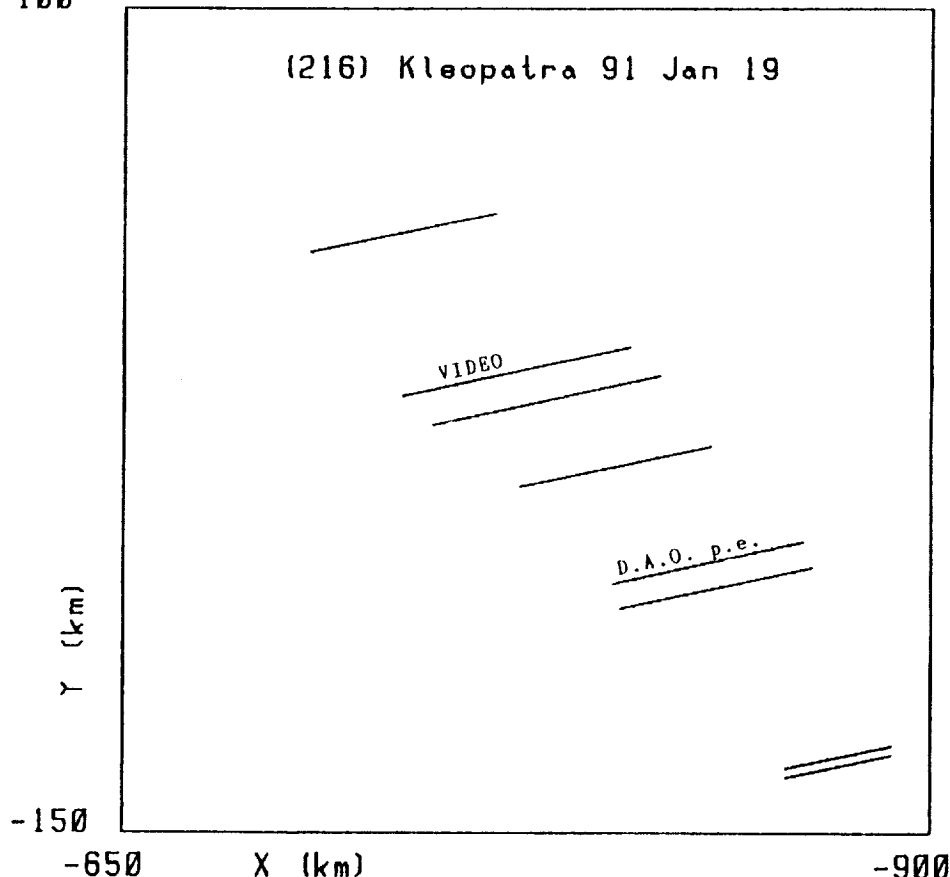
David W. Dunham, Computer Sci. Corp. and Internat'l Occultation Timing Assoc.; Wayne Osborn & Glen Williams, Physics Dept., Central Michigan Univ.; Jack Brisbin, Andreas Gada, Toshio Hirose, Paul Maley, Harold Povenmire, James Stamm, and Jeff Thrush, Internat'l Occultation Timing Assoc. Chris Aikman and Murray Fletcher, Dom. Astrophys. Obs., Victoria, B.C.; Mitsuru Soma, National Observatory, Mitaka, Tokyo, Japan; and Wang Sichao, Purple Mountain Observatory, Nanjing, China

(4) Vesta: On January 4th, Vesta occulted the 7.3-mag. star SAO 93228 as seen from the Great Lakes region. Photoelectric and video recordings were made at 8 sites in Michigan and one in Ohio; at least 11 visual observers obtained additional useful timings as far east as Toronto. Our preliminary analysis shows that the observations are fit well by an ellipse of dimensions 520 km by 482 km. The photoelectric data suggest irregularities departing from the elliptical shape by 15 km or more. If the 1989 August occultation result is considered, the mean diameter of Vesta is probably about 547 km. This value will be refined as lightcurve and pole position data are taken into account.

(381) Myrrha: On January 13th, Myrrha occulted 1.9-mag. Gamma Geminorum, the brightest star yet to be seen covered by an asteroid. The path unexpectedly shifted north, passing directly over the Tokyo region, where the event was monitored photoelectrically at one site, videotaped at two sites, photographed at two more sites, and timed visually at 14 other locations. A preliminary analysis indicates an elliptical outline, 80 km by 120 km, for Myrrha. Those with larger telescopes reported seeing a close companion of Gamma reappear while the bright star was covered. The companion was yellowish and about 8th magnitude; it must have been about 0".04 from the primary. In China, a nationwide campaign was organized, perhaps one of the largest in astronomical history. Over 5000 observers watched the star. The occultation was seen from at least 4 locations in Shandong province.

(216) Kleopatra: On January 19th, Kleopatra occulted 9.1-mag. SAO 115296 across the northern U.S.A. and southwestern Canada. The event was videotaped by Dunham using portable equipment in central New Jersey, and a photoelectric record was obtained with the 1.22-m telescope at the Dominion Astrophysical Observatory in Victoria. Six observers at other locations made visual timings. All of these chords are projected onto the sky plane in the figure below, which shows that Kleopatra's outline was about 55 km wide and about 230 km long! The occultation occurred near the maximum of Kleopatra's large-amplitude lightcurve. Care will be needed to combine this result with the 93 km x 125 km outline obtained during a 1980 October occultation that occurred near minimum light.

100



CALIBRATION OF ASTEROIDAL DUST PRODUCTION RATES THROUGH OBSERVATIONS OF THE HIRAYAMA FAMILIES AND THEIR ASSOCIATED IRAS DUST BANDS

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We determine the contribution of asteroidal collisions to the zodiacal cloud using the dust known to be associated with the Hirayama families as a calibrator. The ratio of the dust production rate associated with the prominent Hirayama families to that associated with the background asteroids is modeled. By working with ratios, we avoid the uncertainties inherent in specifying model dependent parameters (such as impact strength and energy partitioning) which strongly affect collisional outcomes. The observed ratio of the area of the dust associated with the families to that of the dust in the zodiacal background is found by analysis of IRAS data. We compare this ratio to the modeled ratio of family to background dust production rates and comment on whether mutual asteroidal collisions alone are sufficient to supply the zodiacal background.

Väisälä revisited

Eric W. Elst, Royal Observatory at Uccle, Belgium

The method of perihelion orbit of Väisälä (1939) is revisited. It shows that it is still an outstanding method for calculating preliminary orbits, based on only two nights. By taken in account all the astrometric positions of the two nights, it is possible to obtain an even much better orbit. Further, we were able to derive a meaningful orbit from positions that lie less than one hour away from each other.

PRECURSOR MATERIAL FOR COMET FORMATION; S. Engel and J. I. Lunine (LPL/ U of Arizona)

Comet nucleus composition, if formed in the outer solar system, could inherit interstellar as well as solar nebula material. Hence the evolution of precursor material after entering the outer solar nebula disk and before comet accretion was investigated in more detail. Chemical and physical alteration of interstellar material is enhanced in the inner regions, whereas further out some of this material may survive in its initial molecular composition. Physical processes which affect the heating of the particle during entry into the accretion disk are radiation and sublimation. Prior to cometary accretion grain surface reactions could contribute to a change in chemical composition.

The initial conditions for a collapsing molecular cloud and final formation of a accretion disk was taken from calculations by Wood (1984). The decoupled grains in the disk get heated up by drag through the surrounding gas. As test particles we used the Greenberg model of an interstellar grain which consists of a refractory core, covered by organics and overlaid by volatile ices. Sublimation rates of different molecules (volatiles and organics) as a function of infall velocities were calculated. The recondensation of the vapor onto left over grain cores could lead to a core-mantle structure different from the interstellar one. Here the layered structure of organic and volatile material disappears and a mixture of these two components in a homogeneous mantle can be seen. Recondensation under nebula conditions could also avoid some of the kinetic problems associated with clathrate formation. Hence fractionation of gases such as CH₄ and CO will occur as they are co-deposited in the clathrate and amorphous ice structure.

In the above mentioned processes differences could be expected between molecular abundances in the gas phase and the solid phase. Interstellar ices could be chemically different from solar nebula ices.

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THERMAL EVOLUTION AND PHYSICAL DIFFERENTIATION OF THE SUBSURFACE LAYERS OF SHORT PERIOD COMETS. CRUST FORMATION; S. Espinasse, A. Coradini, C. Federico, and F. Capaccioni, IAS-Reparto Planetologia, Viale dell'Università, 11 00185 ROMA ITALY

The evolution of the subsurface layers of a short period comet has been studied. Particular attention was given to the variations of porosity and changes of composition of the superficial layers due to sublimation-recondensation phenomena, to gas diffusion processes through the pore system and to the sputtering of dust particles. Our nucleus model is composed of a water ice, CO₂ ice and dust mixture in specified proportions. The icy matrix is assumed to be porous and crystalline.

The model is based on the resolution of two symmetric diffusion equations through the whole nucleus, one describing the transport of matter and the other the transport of heat. These equations are linked by the source term which accounts for production or loss of gas in terms of matter or of latent heat under two assumptions. First, we assume that the water vapor present in the pore system acts as a perfect gas. Second, we consider that sublimation and recondensation are instantaneous in order to maintain locally the thermodynamic equilibrium between the solid phase and its vapor. Under these assumptions, the source term depends on the variation of the pressure due to vapor diffusion and on the variation of the saturation pressure of the vapor due to the evolution of the temperature. The diffusion regime, Knudsen or viscous, depends on the mean free path of the molecules of gas through the pore network considered as a system of cylindrical pipes. The possibility is given to the dust particles to be ejected from the surface of the nucleus according to the force balance between gases fluxes, gravity and centrifugal forces and to the dust particles size distribution.

The calculations are performed for a nucleus on the orbit of P/Dutoit - Hartley because it is one of the possible targets for the Rosetta/CNSR mission. Different nucleus compositions with different CO₂/H₂O ice ratios and different dust/ice ratios are investigated. Results are presented on the evolution of the stratigraphy of the nucleus and of the production rates of CO₂, H₂O and dust particles as a function of the heliocentric distance. Several phenomena are evidenced, such as the depletion of CO₂ ice in the subsurface layers and the possible presence of a dust layer at the nucleus surface.

INJECTING ASTEROID FRAGMENTS INTO RESONANCES

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& Cl. Froeschle' (OCA - Observatoire de Nice, France)

Most meteorites and near-Earth asteroids (NEAs) are widely believed to be asteroidal fragments, coming from the asteroid belt through chaotic dynamical routes, associated with mean motion and secular resonances. We have tried to model and assess in a quantitative way the first part of this process, namely the ejection of fragments from cratering or break-up events undergone by the existing asteroids as a consequence of impacts, and the chance insertion of the escaping fragments into the "dangerous" regions of the phase space close to the 3:1 (mean motion) and $g=g_6$ (ν_6) (secular) resonances. For every parent asteroid, the efficiency of this process depends on several factors: (i) the amount of ejected material per unit time; (ii) the mass vs. ejection velocity distribution of the fragments; (iii) the escape velocity of the parent body; (iv) the ΔV required to approach a resonance surface; (v) the width of the strip surrounding the resonance surfaces where chaotic eccentricity increases are possible. By varying some model parameters, we have estimated the fraction of ejected fragments falling in the two resonances from all the existing asteroids larger than 50 km and orbiting inside 2.8 AU. The results show that most meteorites and NEAs can be generated by a small fraction of the overall asteroid population, mostly located in the vicinity of resonances. Both resonances are probably effective channels for fragment collection and delivery, although they sample in a different way the orbital elements and the physical properties (size and taxonomic type) of the parent objects.

IUE Observations of Comet P/Tempel-2 During 1988

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We summarize the results of observations made between 10 June and 18 December 1988 with the *International Ultraviolet Explorer* (*IUE*) of comet P/Tempel-2 during its 1988 apparation. The derived water production rate (c.f. Roettger *et al.*, *Icarus*, **86**, 100, 1990) and relative gas/dust ratio are compared with those of P/Halley, observed with *IUE* in 1985-86, and other potential CRAF target comets, P/Kopff and P/Tempel-1, both observed with *IUE* in 1983.